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LITHOSTRATIGRAPHY OF THE PRE-CENOMANIAN CLASTICS OF NORTH WADI QENA, EASTERN DESERT, EGYPT

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ABSTRACT

Underlying the definite marine Cenomanian sediments and overlying unconformably the Precambrian Basement in north W. Qena-W. El Dakhl landstretch (Eastern Desert), is a superbly exposed clastic succession of "Nubian Facies". It attains a thickness of approximately 200 m and extends in age from Cambrian to Early Cretaceous. It is punctuated by regional unconformities as well as several paleosol horizons.

In G. Somr El Qaa - W. Hawashia area, the Pre-Cenomanian section is differentiated into three rock units: the Cambro-Ordovician Araba Formation, the Pre-Carboniferous-Ordovician (?) Naqus Formation, and the Lower Cretaceous Malha Formation. Northwards, approximately from W. Um Arta, the Naqus Formation is gradually reduced in thickness and is overlain unconformably by the Carboniferous Abu Thora Formation. On the other hand, the Abu Thora Formation underlies unconformably the northerly thickening Malha Formation. At W. El Dakhl, the Naqus Formation is entirely eroded and the Abu Thora Formation overlies unconformably different levels of the Araba Formation.

The present study does not confirm the presence of the Carboniferous formations mentioned by earlier workers in the southern part of the present area.

INTRODUCTION

A Pre-Cenomanian clastic sequence of "Nubian facies", reaching an aggregate thickness of about 200 m., extends along the area from W. El Dakhl to W. Qena, Eastern Desert. It consists mainly of shallow marine and continental sandstones with subordinate mudstone and conglomerate beds. It is, generally, poorly fossiliferous and no index body fossils could be observed except for some trace fossils and badly preserved plant remains.

The investigated area lies between Lats. 28° 28°-15' - 28° 45' N and Longs. 32° 00'-32° 30'E (Fig. 1). It represents the southeastern scarp of the South Galala Plateau and the southern slope of G. Somr El Qaa. The "scarp and vale" are the characteristic landforms of this area which consists mainly of west to southwest gently tilting cuestas having north to northeast steep sloped scarps. A number of well marked wadies cutting these cuestas debouch either in the Nile Valley through W. Tarfa and W. Murr or in the Gulf of Suez via W. El Dakhl, W. Ghazala and W. Hawashia. The Pre-Cenomanian clastics occupy a narrow strip along this area and form the pediment, foot and scarps of the cuestas. Also, they occur as isolated buttes and conical hills standing above the floors of the semiclosed depressions that are faced by the Basement highs from the east and by the eastward concave retreated Cretaceous and Eocene scarps from the west.

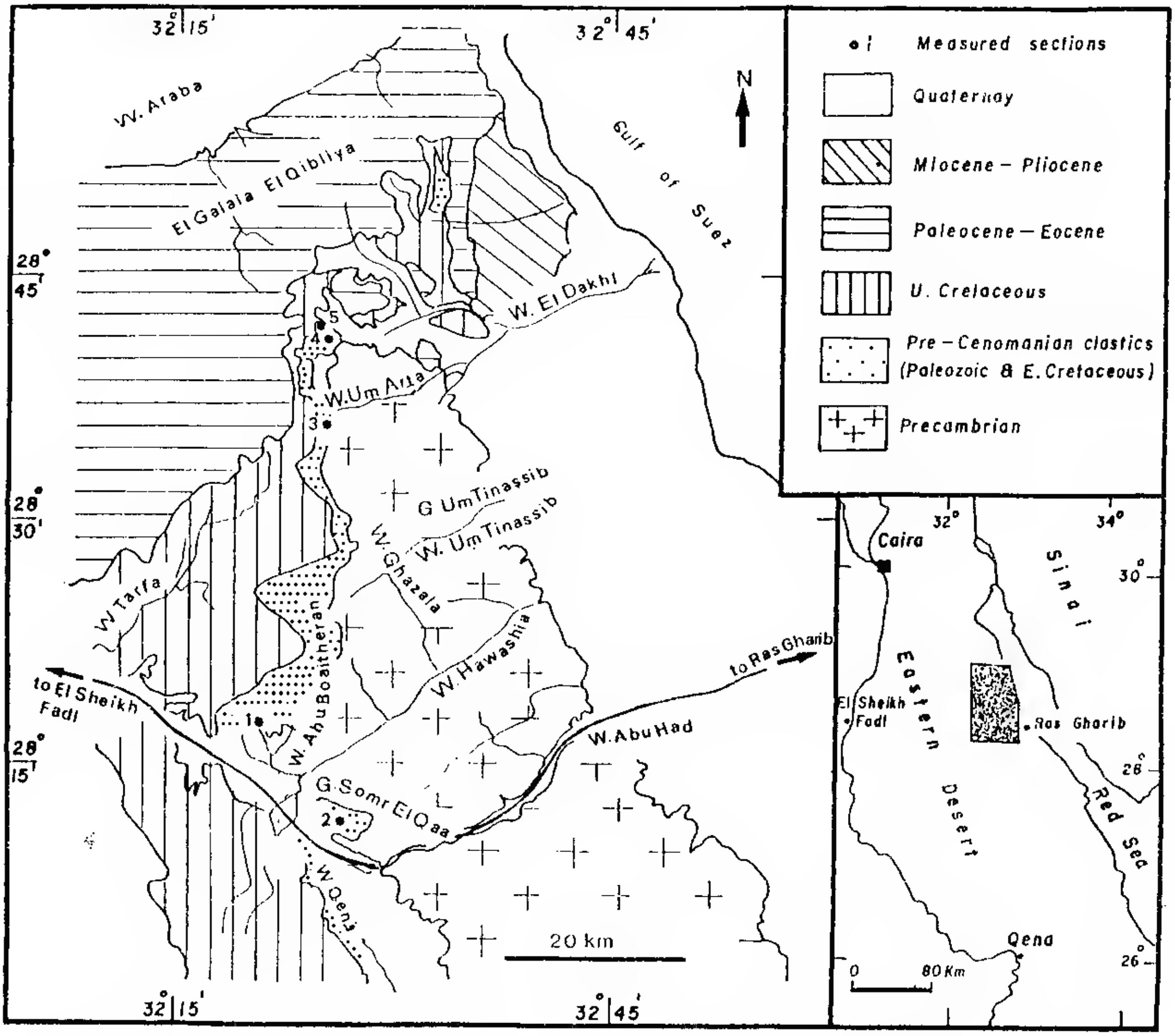

Fig. (1) Simplified geological map of North W. Qena-W. El Dakhl district, Eastern Desert, Egypt. (based on Geological map of Egypt, sheet No. NH 36 SW, Beni Suef; Conaca, 1987).

The main aim of this work is to study the stratigraphy and analyze briefly the depositional environments of these siliciclastic sequences. Four stratigraphic sections, representing these clastics along the study area, are measured and sampled (Fig. 1). The lithologic aspect, the physical and biological sedimentary structures and the thickness of these sequences are described, analyzed and discussed.

LITHOSTRATIGRAPHY

Prior to the last decade, the detailed stratigraphy of the Pre-Cenomanian sequence of the area between W. El Dakhl and W. Qena had not been achieved. It was formerly known as "Nubia Sandstone" or Early Cretaceous "Nubian Sandstone" (Hume, 1911; Attia and Murray, 1962; Said, 1962 & 1971; Gezeery and Marzouk, 1972; and Kassab, 1982 & 1985). Since the early

eighties, several teams of geologists have curiously depicted and sometimes inspected, in detail, this sequence, particularly its Paleozoic portion, where it is differentiated into several formal rock units instead of the debatable name "Nubian Sandstone" (Table 1). From these studies, it is worthy to mention the works of Issawi and Jux (1982); Klitzsch (1984 & 1986); Klitzsch and Lejal Nicol (1984); Barakat *et al.* (1986); Bhattacharyya and Dunn (1986); Bandel *et al.* (1987): Hendriks *et al.* (1987); Klitzsch and Wycisck (1987); Schandelmeier *et al.* (1987); Kuss (1989); Klitzsch *et al.* (1990); and Seilacher (1990).

The present field stratigraphic investigation, equipped with the valuable data from the previous studies, revealed the subdivision of the Pre-Cenomanian clastics in the study area into the following rock units (from top to base):

4- Malha Formation (Early Cretaceous)

----------Unconformity----------

3- Abu Thora Formation (Early Carboniferous)

---------- Unconformity ----------

2- Naqus Formation (Pre-Carboniferous-Ordovician ?)

1- Araba Formation (Cambro-Ordovician)

These formations are differentiated and generally dated on the basis of their: (1) distinct colour, mineralogy, physical-and biological sedimentary structures; (2) contents of ichnofossils and plant remains; (3) stratigraphic set-up; and (4) comparison to the earlier results in Sinai and Gulf of Suez, taking into account the previously described similar rock units.

Araba Formation

Author: the name Araba Formation is registered to Hassan (1967 in Said, 1971), but indeed, the former author (1967) did not apply this name.

Type area: Araba-Durba area, southwest Sinai, Egypt (Lat. 28° 24'and Long. 33° 26').

Reference section: W. Abu Boaitheran, a tributary of W. Hawashia, north of G. Somr El Qaa area (Lat. 28° 19'and Long. 32° 24), Eastern Desert.

Thickness: 120 m in the type area (Said, 1971). According to Issawi and Jux (1982), the Araba Formation varies in thickness from 100 m in the type locality to 40 m in Um Bogma area and 25 m in Eastern Desert. In the reference section and W. Um Arta, this formation reaches 50-60 m thick. Further north, at W. El Dakhl, it is intensively eroded where its preserved thickness ranges from 2 to 10 m.

Boundaries: As in the type locality, the Araba Formation in the study area nonconformably overlies a corrugated surface of the Precambrian Basement and underlies, without a visible unconformity, the Pre-Carboniferous Naqus Formation. Northwards, at W. El Dakhl, however, it unconformably underlies the Carboniferous Abu Thora Formation (Pl.1.a).

Description: In the type locality, the Araba Formation consists of varicolored and laminated sandstone and sandy clays with abundant *Scolithos* and *Cruziana* tracks (Said, 1971; Issawi *et al.*, 1981; and Issawi and Jux, 1982). Bhattacharyya and Dunn (1986) added that this formation comprises repeated coarsening upward subunits of red and green mudstone, grading above into red and brown arkosic sandstone.

Everywhere in the study area, the Araba Formation is recognized at the first glance by its striking overall reddish colour. It is made up of alternating flat and lenticular beds of sandstone and mudstone, grading in the upper half to invariably cross-bedded coarse-grained to gravelly sandstone. Two members can be distinguished which are easily traceable along a regional strike for at least 40 km along the investigated area (Figs. 2 and 3). These members are:

Lower Mudstone-Sandstone Member (*Cruziana*-bearing Member)

This member is characterized from the upper one by its distinct dark red, chocolate brown and green colours as well as its flat, rippled, wavy and

<table>
<tr><th colspan="2">Kassab (1982, 1985) north W.Qena</th><th colspan="2">Issawi & jux (1982) W.Qena-W.El-Dakhl</th><th colspan="2">Klitzsch (1986) Klitzsch et. al. (1990), W.Qena</th><th colspan="2">Bandel et al. (1986) W. Qena</th><th colspan="2">Hendriks et al. (1987) W. Qena</th><th colspan="3">Present work</th></tr>
<tr><th></th><th></th><th></th><th></th><th></th><th></th><th></th><th></th><th></th><th></th><th></th><th>W. El-Dakhl</th><th>G. Somr El-Qaa</th></tr>
<tr><td>Cenomanian</td><td>Galala Fm.</td><td>Cenomanian</td><td>Galala Fm.</td><td>Cenomanian</td><td>Galala Fm.</td><td>Cenomanian</td><td>Atrash Fm.</td><td>Cenomanian</td><td>Galala Fm.</td><td>Cenomanian</td><td colspan="2">Galala Fm.</td></tr>
<tr><td></td><td></td><td>Early Cretaceous</td><td>Malha Fm.</td><td>Early Cretaceous-Cenomanian</td><td>W. Qena Fm.</td><td>Early Cretaceous</td><td>Dakhl Fm.</td><td>Early Cretaceous-Cenomanian</td><td>W, Qena Fm.</td><td>Early Cretaceous</td><td colspan="2">Malha Fm.</td></tr>
<tr><td rowspan="5">Aptian - Albian</td><td rowspan="5">Nubia Fm.</td><td>Premo-Carboniferous</td><td>Gilf Fm.</td><td rowspan="4">Early & Middle Carboniferous</td><td rowspan="4">Somr El-Qaa Fm.</td><td rowspan="5">Early Carboniferous</td><td rowspan="5">Um Bogma Fm.</td><td rowspan="5">Paleozoic</td><td rowspan="5">Um Bogma Fm.</td><td>Early Carboniferous</td><td>Abu Thora Fm.</td><td></td></tr>
<tr><td>Devonian</td><td>Wadi Malik Fm.</td><td rowspan="2">Pre-Carboniferous (Ordovician ?)</td><td colspan="2" rowspan="2">Naqus Fm.</td></tr>
<tr><td>Silurian</td><td>Naqus Fm.</td></tr>
<tr><td rowspan="2">Cambro-Ordovician</td><td rowspan="2">Araba Fm.</td><td rowspan="2">Cambro-Ordovician</td><td colspan="2" rowspan="2">Araba Fm.</td></tr>
<tr><td>Early Cambrian</td><td>Araba Fm.</td></tr>
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Table (1) : Different Lithostratigraphic Classifications and Nomenclatures of the Pre-Cenomanian Clastics of W. Qena-W. El-Dakhl Area.

lenticular bedding geometry. It commonly starts with a pebbly sandstone unit (1-6 m thick) with conglomerate lenses. Its sole is frequently armoured by scattered angular pebbles and cobbles of vein quartz and locally reworked granitic and other igneous rock fragments. This unit consists either of a single or more than one lenticular sandstone bodies which internally display horizontal and low-angle cross-bedding and lamination. The lateral persistence and thickness

of these bodies vary discriminantly even in one and the same place. These variations were largely controlled by the original uneven paleo-relief of the underlying Basement surface. Above the basal unit, the rest of this member is represented by alternating and intertonguing beds of variegated micaceous sandstone and mudstone. They constitute two or three similar coarsening upward subunits which are internally characterized by thin to thick wavy and connected lenticular bedding with abundant ripple marks, ripple cross-lamination, flaser lamination, parallel lamination, erosional sole marks and desiccation cracks (Pl.1-b, c, and d). These units are a good hardbinger for the first ingression of the sea over the study area as documented from its marine trace fossil content. The top part of this member is densely penetrated by short and thin vertical tubes, giving a characteristic burrow mottling, which is in parts associated with diffusion colours and scattered iron-concretions. Due to the lenticular geometry of the sandstone and mudstone layers, their frequencey, relative to each other, vary from place to place, however the mudstone and fine grained sandstone facies with striking green colours are more abundant northward, particularly at W. Um Arta.

The lower member extends along the study area with a thickness ranging between 20 and 25 m. However, in local outcrops, at the western upper-reaches of W. Abu Boaitheran and in the southwestern footslope of G. Somr El Qaa, it wedges discriminantly, reaching up to 5 m in thickness, or is totally missing and the sandstones of the upper member rest directly on the Basement rocks. In such places, the reduced thickness of this member is represented by poorly bedded, ill-sorted, very immature and in situ reworked arkosic conglomerate and sandstone, rich in disintegrated granitic fragments and kaolinitic matrix.

Upper Sandstone Member (*Scolithos*-bearing Member)

Synonymy: Section of Somr El Qaa Formation described by Klitzsch (1986) and Klitzsch *et al.* (1990) in Somr El Qaa area.

This member is essentially made up of pale red sandstone with several conglomerate lenses (Fig 2). The mudstone fraction is rare and restricted to the uppermost part. Its lower contact with the underlying member is sharp and marked by an abrupt change from distinctive red and mottled mudstone and fine grained sandstone to well developed trough and tabular gravelly, very coarse grained sadnstone. At local outcrops in the southwestern footslope of G. Somr El Qaa, particulary where the lower member thins remarkably, its burrow mottled top is separated from the upper member by a poorly sorted and massive conglomerate bed (30 cm thick) containing angular Basement pebbles and cobbles. Laterally, and concomitantly with the thickening of the lower member, the conglomeratic bed wedges gradually and splits into very thin lenses that underlie and/or intertongue with the basal cross-bedded sandstone of the upper member. Furthermore, in some restricted places, west of W. Abu Boaitheran, the successively younger beds of this member directly overlap in southwest direction different levels of the Basement blocks. The interval between these beds and the Basement surface is occupied by thin, hard layers of immature conglomeratic sandstone, rich in highly kaolinitized Basement rock fragments.

The sandstones of this member exhibit a wide spectrum of grain size, grading from fine sand to pebble sizes; however, the coarse to very coarse sand grades are common. They are micaceous with angular quartz grains and scattered kaolinized granitic grains and kaolinitic pseudomatrix. The sandstone layers are organized into noncyclic to fining-upward subunits that vary in thickness from 0.5 to 3 m. Some subunits start with erosive bases showing small-scale channels as well as scour and fill structures. Internally, the sandstone is commonly tabular and trough cross-laminated showing a NE to NNW paleocurrent direction. Low-angle and horizontal lamination as well as herringbone cross-bedding are currently

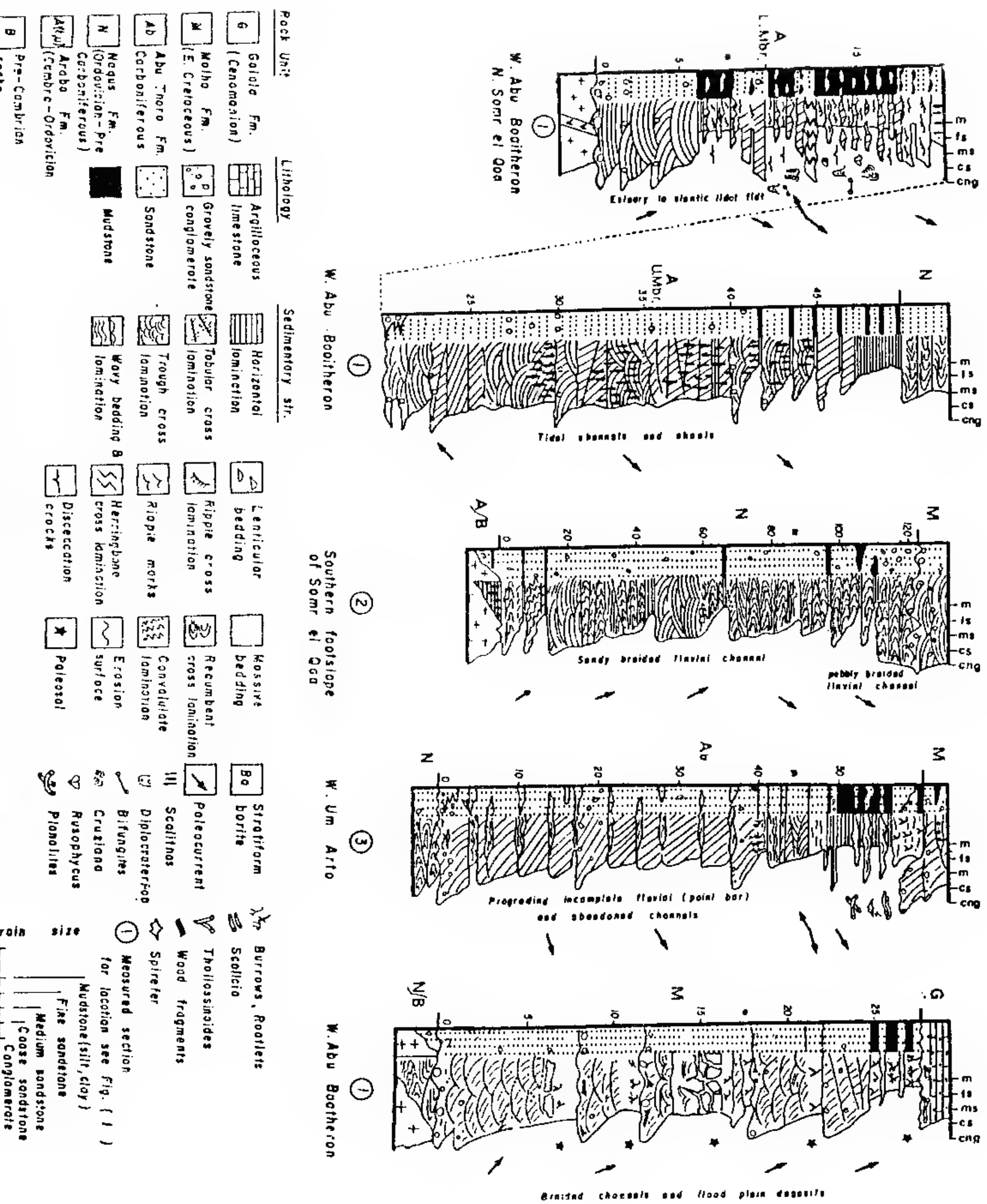

Fig.(2) : Lithostratigraphic sections of Araba, Naqus, Abu Thora and Malha Formations.

recorded. Near the upper part of this member, the sandstone subunits display a fining-upward regime ending with horizontal laminated red mudstone and fine grained sandstone. In Somr El Qaa section, several Basement-bearing conglomeratic lenses are recorded in the bases of these subunits. Along the study area, the topmost part of this member is represented by thin to thick laminated white mudstone and fine-grained sandstone.

The most diagnostic feature of this member, particularly in the southern sector of the study area, is its population with long *Scolithos* burrows which densely penetrate the horizontal and cross-bedding (Pl.1-e). Northward, at W. Um Arta, these burrows are less distinctive and their ghosts are only met with in a few horizons. Meanwhile, in the northern outcrops, dumb-bell openings similar to *Bifungites* are more common in the lower part of this member.

The upper member is widely distributed along the study area with a thickness varying from 30 to 40 m (Fig. 3).

Fossils and geologic age: The Araba Formation seems to be barren of any body fossils but yielding several ichnogenera. Based on the *Trilobites* and *Bilobites* tracks recorded by Weissbrod (1969) and the debatable finding of *Stromatolites* by Omara (1972), this formation is assigned to Early Cambrian in its type locality (Sinai). Issawi and Jux (1982) determined Cambro-Ordovician age from their trace fossil collection including *Scolithos coensis*, *Cruziana sp.*, *Allocotichnus sp.*, *Rusophycus sp.*, *Dimorphicnus sp.*, *and Diplichnites sp.* Bandel et *al.* (1987) correlated the sediments of this formation, in W. Qena area, with the Um Bogma series (Kostandi, 1959) of Sinai and consequently regarded it to be of Carboniferous age. Klitsch and Wysick (1987), and Klitzsch *et al.* (1990) dated the Araba Formation to Early Cambrian age relying on the trace fossil collection of Seilacher (1990) via *Cruziana cf. nabataeica*, *C. Salomonis*, *C. aegyptica*, *Bergauria sucta, Dimorphichnus cf. obliquus*, and *D. C.f. quadarfidus.* In the study area, the lower mudstone-sandstone member is rich in *Cruziana aegyptica, Cruziana arizonensis, Cruziana sp, Rusophycus sp., Dimorphichnus sp., Diplocraterion sp., Bergauria sucta, Arenicolites sp.*, and other problematic species (Pls. 2 and 3). Abundant *Scolithos* burrows and *Bifungites* having globular arrowheads are recorded in the upper sandstone member. Seilacher (1983) mentioned that the trilobite burrows are rather distinctive in the Lower Paleozoic; they became increasingly rare from Devonian and are not contained in the Carboniferous assemblages. In 1990, he considered the ichnospecies *Cruziana aegyptica and Bergauria sucta* to be of Early Cambrian age, while the dumb-bell *Bifungites is of Cambrian to Ordovician age, but being less distinctive because it can be related to the Diplocraterion,* which extends to the whole Phanerozoic. Based on the collected ichnogenera and species, the Araba Formation in the study area is assigned to Cambrian -and probably Ordovician age.

Geographic distribution and correlation: The thickest outcrop (120 m) of the Araba Formation occurs at the type locality "Araba-Durba area", southwest Sinai (Said, 1971; and Issawi *et al.*, 1981). Northwards, in west-central Sinai, this thickness is rather reduced (Issawi and Jux, 1982), and the Araba Formation is stratigraphically equivalent to the Cambro-Ordovician rock units (Sarabit El Khadem, Abu Hamata and Nasib formations) proposed by Soliman and Abu El Fetouh (1969) and Kora (1984). It could be also correlated with the rocks of the Amudei Shelomo, Hakhlik, Mikhrot, and Shehoret formations of Yam Suf Group described by Weissbrod (1969) in southern Israel and Sinai. In the subsurface of the Gulf of Suez, the Araba Formation is possibly equated to the informal "Nubia D" given by oil companies. Along the study area, the Araba Formation is well developed in the district between W. Um Arta and G. Somr El Qaa (Fig. 3). North as well as southwards of that district, this unit rapidly decreases in thickness until it disappears. It is worthy to mention here that the present recognized lower "mudstone-sandstone"

PLATE 1

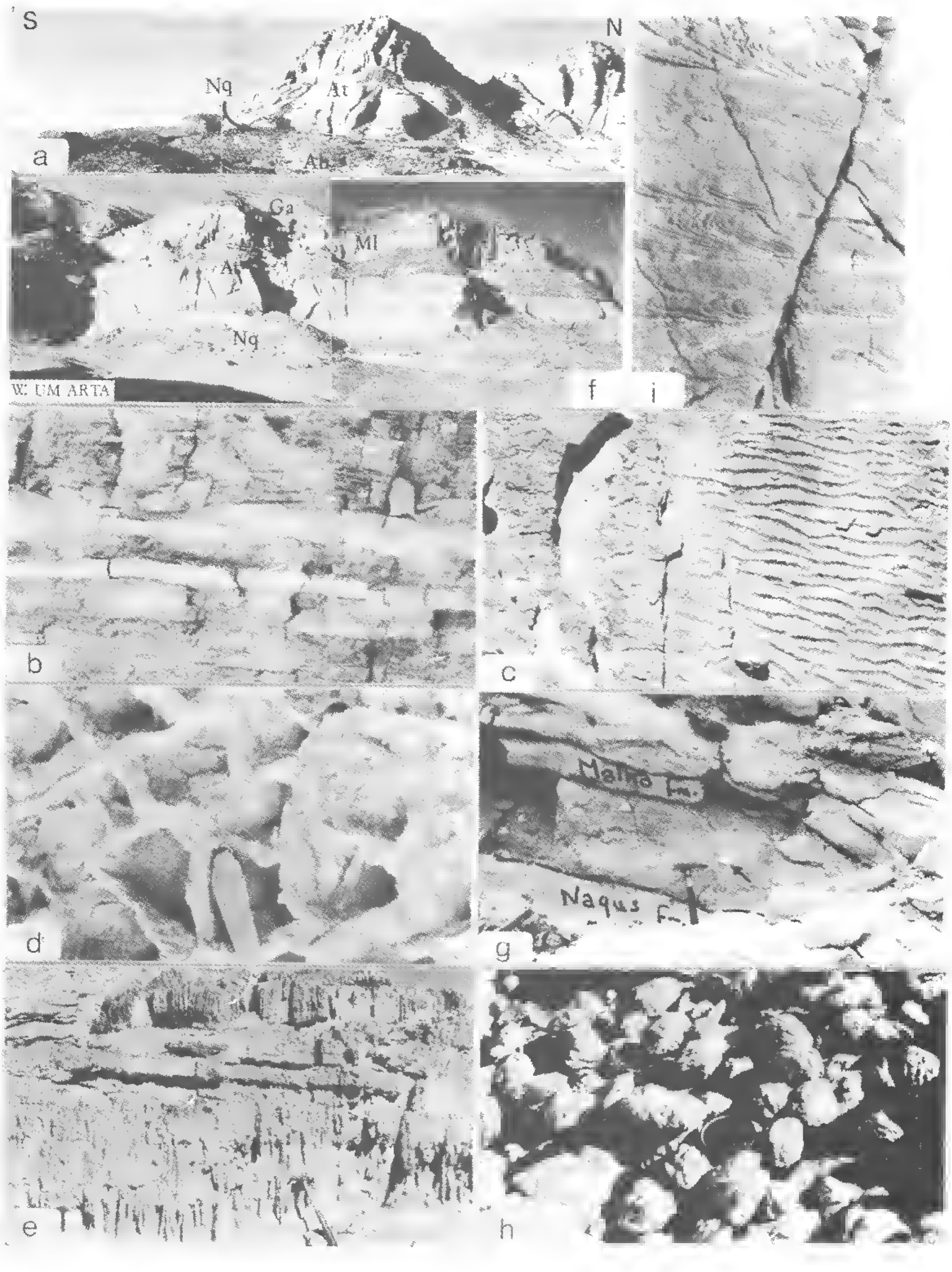

PLATE 1

a) The Cambro-Ordovician Araba Formation (Ab) unconformably underlies the Lower Carboniferous Abu Thora Formation (At) with local remnants of the eroded Lower Paleozoic Naqus Formation (Nq), W. El Dakhl.

b) Connected lenticular bedding in the lower member of the Araba Formation, W. Abu Boaitheran, north Somr El Qaa.

c) Slightly sinuous and bifurcated wave ripples in the lower member of the Araba Formation, W. Abu Boaitheran.

d) Desiccation cracks filled with sandstones in the lower member of the Araba Formation, W. Abu Boaitheran.

e) Population of long *Scolithos* burrows in the upper member of the Araba Formation, W. Abu Boaitheran.

f) Panoramic view showing the pre-Cenomanian formations of W. Um Arta, 8 km south of the section photographed in Fig. (a). Notice the considerable thickness of the Naqus Formation (Nq) which directly underlies the Abu Thora Formation (At). Ml = Malha Formation; G = Galala Formation.

g) White angular sandstone clasts reworked from the Naqus Formation in the basal conglomeratic sandstone of the Malha Formation, W. Abu Boaitheran.

h) Barite-cemented sandstone concretion (rosette-like forms) marking the contact intervals between the Naqus and Malha formations, W. Abu Boaitheran.

member may represent the entire Araba Formation (25 m thick) described by Klitzsch *et al.* (1990) in north W. Qena area. On the other hand, Klitzsch *et al.* *(op. cit.)* considered the cross-bedded sandstone units with abundant *Scolithos* burrows, which constitute the present upper member, as a Carboniferous rock unit and called it "Somr El Qaa Formation". In fact, the majority, if not all, of the previous workers and even Klitzsch (1990) have described the *Scolithos-rich* sandstone beds, as the essential facies characterizing the Araba Formation in Sinai and Gulf of Suez (e.g. Said, 1971 Issawi *et al.*, 1981; Issawi and Jux, 1982; Beleity *et al.*, 1986; and Bhattacharyya and Dunn, 1987). Adding to this, in the type section of what is regard as "Somr El Qaa Formation", at G. Somr El Qaa, no concrete paleontologic or stratigraphic evidences indicating the Carboniferous age for that member. It seems that, in southwest W. El Dakhl, Klitzsch *et al.* (1990) lumped the sandstones of this member with the unconformably overlying sandstones of definite Carboniferous age (Abu Thora Formation), which is totally missing in the south at Somr El Qaa area. Accordingly, the Previous Carboniferous dating of this sandstone in Somr El Qaa area is not correct and misleading, if it was based on the above confusing and invalid correlation only.

Naqus Formation

Synonymy: Somr El Qaa Formation, Klitzsch (1986) and Klitzsch *et al.* (1990).

Author: the term Naqus Formation is attributed to Hassan (1967, in Said, 1971).

Type area: Araba-Durba area, SW Sinai, Egypt (Lat. 28° 24'N and Long. 33° 26'E).

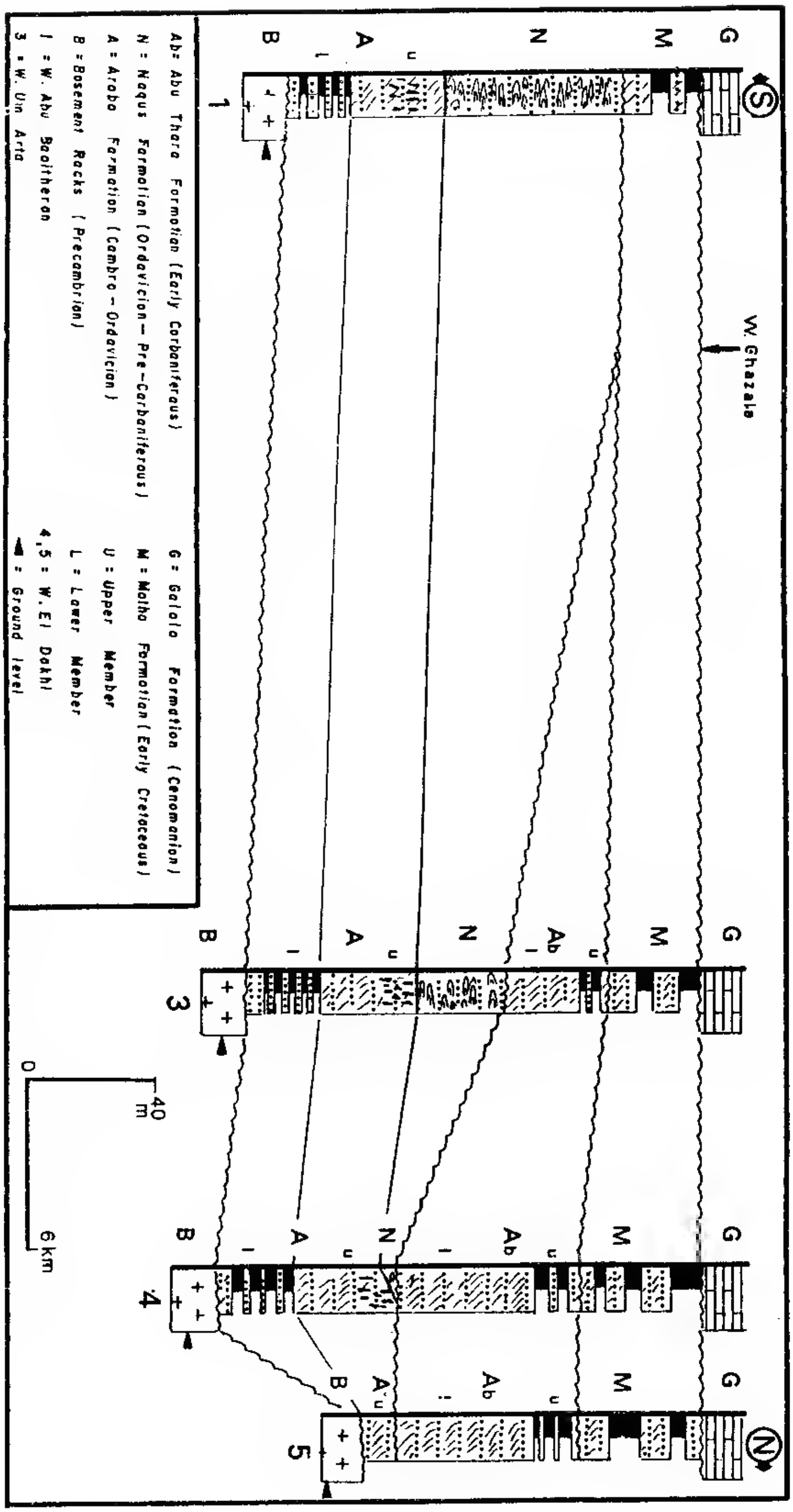

Fig.(3) Lithostratigraphic Correlation of Pre-Cenomanian sections studied along N-S strike of Somr El Qaa - W. El Dakhl area.

Reference section: Southern footslope of G. Somr El Qaa, north El Sheikh Fadl - Ras Gharib asphaltic road, Eastern Desert, Egypt.

Thickness: reaches about 462 m in the type locality (Said, 1971). In the study area, it is highly variable but with general northward reduction. In the southern sectors, the thickness ranges between 50 and 60 m hut locally increases up to 120 m in the reference section. In the north, it wedges out to less than 30 m at W. Um Arta, while further north, the formation is totally missing at the northwestern reaches of W. El Dakhl (Fig. 3).

Boundaries: In the type locality, the Naqus Formation overlies the Araha Formation and underlies the Carboniferous Durba Shale (Said, 1971; and Issawi *et al.*, 1981). According to Issawi and Jux (1982), the Naqus Formation underlies the Devonian "Wadi Malik Formation". In most places of the study area, this formation follows the Araba Formation, without any visihle unconformity, hut in restricted occurrences, in the west of W. Abu Boaitheran, its layers overlap nonconformably the Precambrian Basement rocks. On the contrary, the upper boundary of this formation represents a regional unconformity allover the study area. It is overlain hy different rock units, where in Somr El Qaa - W. Hawashia area it underlies disconformahly the Lower Cretaceous "Malha Formation", while, in the north, approximately from W. Um Tenassib, it is unconformably overlain hy the Lower Carboniferous "Ahu Thora Formation" (Pl.1-f). In fact, due to the predominance of white sandstone facies and the scarcity of index hody fossils in the Naqus and the overlying Ahu Thora or Malha formations, the contact and distinction between them could he confused in some places, if they are studied without a detailed regional inspection of their sedimentary structures and sedimentological history. This prohlem seems to he responsihle for the recent controversy in the rock stratigraphic suhdivisions proposed hy previous workers (*e.g.* Issawi and Jux, 1982; Kassab, 1982 and 1985; Bandel *et al.*, 1987; and Klitzsch *et al.*, 1990). However, the disconformahle contact between the Naqus and the Malha formations could he detected, particularly in vertical cliffs, hy an erosional surface, exhibiting a relief gradient up to 2 m with accumulation of basal conglomerate containing quartz pebbles as well as white sandstone and mudstone clasts reworked from the underlying Naqus Formation (Pl.1-g). Other guide features could he also used in marking this contact, including: 1) the radical change from chalky-like white sandstone and kaolinitic mudstone of the Naqus Formation to brownish yellow and grey conglomeratic sandstone cemented hy harite in the base of the Malha Formation; 2) the clear transition from well developed trough, tahular, and recumhent cross-lamination of the Naqus Formation to truncated mezoscopic channels with internal indistinct cross-and massive bedding in the Malha Formation; 3) the ahundance of large harite rosettes and barite-veins, ornamenting the horizon in which the contact occurs (Pl.1-h); and 4) the flooding of loose, large and well-rounded quartz gravels along the contact intervals.

On the other hand, the boundary between this formation and the overlying Carboniferous Abu Thora Formation is marked hy an erosional surface that lacks any local relief gradient, and is manifested hy the occurrence of lenticular layers of sandy conglomerate that are truncated laterally hy large scale cross hedded pebbly sandstone, up to 3 m set thickness. These rocks are mineralogically very mature in comparison to the underlying sandstones of the Naqus Formation.

Description: In the type section, the Naqus Formation is made up of white to pale hrownish sandstone with notable "fluvio-glacial" dripstones of quartz pehhles and cobbles (Issawi *et al.*, 1981). Bhattacharyya and Dunn (1986) descrihed this formation as consisting of several sandstone hodies, heing lenticular and fining-upward. In the study area, the Naqus Formation is a unique sandstone unit, consisting of several noncyclic to fining-upward sandy hodies ranging hetween 0.5 and 2 m in thickness (Fig. 2). These bodies are invariably cross laminated, indicating NW-NE dispersal pattern. They commonly display low-angle trough cross-lamination with

cosets of planar and tangential types, being interrupted by reactivation surfaces and thin intervals of horizontal stratification. The cross-set thickness varies from 10 cm to 1 m. The most outstanding feature of these bodies is the frequent occurrence of deformed cross sets, including overturned, isoclinal, recumbent and convolute lamination (Pl.1-i). These syndepositional deformation structures are currently met with everywhere, and can be used as a lithostratigraphic marker for this formation. They were described in the Naqus Formation at different sections of Sinai, Gulf of Suez, and G. El Zeit area (Bhattacharyya and Dunn, 1986; Bandel *et al.*, 1987; Ghanem and El Mansey, 1991; and Darwish, personal communication). The sandstone building up this formation has a vivid chalky-like white colour with yellowish brown tarnish. It is weakly consolidated, generally medium to coarse grained and fairly well sorted, but with scattered quartz granules and pebbles. Fine to very fine grained sandstone fractions are also encountered, particularly in the middle part. There are no considerable clayey intervals in this formation, except for some poorly kaolinitic white mudstone lenses in the top of some sandstone bodies. The majority of the grains are quartz with observable components of altered feldspar grains and granitic clasts, giving a white speckled appearance to the sandstone. The uppermost part, up to 20 m thick, of this formation contains a lot of well rounded, discoidal large quartz gravels (up to 5 cm in size). These gravels form horizontal and cross-layers that are mostly of a single clast thiek, and may represent or armour internal erosion surfaces between the cross-laminated sandstone beds (Pl.4-a). Some intraformational conglomerate lenses, consisting of locally reworked sandstone fragments, are also encountered (Pl.4-b). This gravelly sandstone part is only recorded in the sections south of G. Somr El Qaa, where the thickest outcrop of the Naqus Formation is measured. Northwards, it is partially to completely eroded and the quartz gravels are reworked and accumulated in the basal part of the Malha Formation. Further to the north, at W. Um Arta, where the Pre-Carboniferous intensive erosion reached the middle intervals of the Naqus Formation, these large gravels are completely missing.

Fossils and geologic age: The Naqus Formation is generally barren of any organic remains except for some tube structures recognized, in its top, by Issawi *et al.* (1981). The absence of fossils hinders its age assignment, which in all previous studies is a matter of estimation. Hassan (1967) considered it to be of Carboniferous or older age. Issawi *et al.* (1981) gave a Cambrian-Early Carboniferous age based on the correlation with the "Shehoret" and "Netafim" formations of Negev, Israel. Issawi and Jux (1982) interpreted this formation as fluvio-glacial deposits left from the great Sahara glaciers, that had covered vast parts of nortwestern Africa during the Upper Ordovician-Silurian period. Bandel *et al.* (1987) correlated it with the "Um Bogma Series" in Sinai and consequently assigned it an Early Carboniferous age, following Kostandi (1959). Klitzsch (1990) assigned this formation, in Sinai, an Early Cambrian age. In the meantime, he confused it, in north W. Qena, with the Carboniferous sandstone and called it "Somr El Qaa" Formation. In the present study, the Naqus Formation is assigned to be of Ordovician - Pre-Early Carboniferous age?, based directly on its stratigraphic position. It overlies the Cambro-Ordovician "Araba Formation" and underlies either the Early Carboniferous Abu Thora Formation at W. Um Arta, or the Carboniferous Durba Shale in the type area. According to Klitzsch (1990), the uppermost beds (20-50 m thick) of the Naqus Formation, in its type locality, indicate paleontologically an Early Carboniferous age. Accordingly, he did not relate these intervals to the Naqus Formation but correlated them with the Carboniferous Abu Thora Formation in the Um Bogma area.

Geographic distribution and correlation: The Naqus Formation is well exposed on both sides of the Gulf of Suez, particularly along its southern half (W. Feiran and Abu Durba-Araba areas in the east of the Gulf, and W. El Dakhl, W. Qena,

and G. El Zeit in the west). From Central Sinai to the western side of the Gulf of Aqaba, the facies of the Naqus Formation can be stratigraphically correlated with the sandstones of the Adaedia Formation of Soliman and Abu El Fetouh (1969) or with the Netafim Formation described by Weissbrod (1969) in southern Israel and Sinai. The maximum thickness (462 m) of this formation is recorded in its type locality, Araba-Durba area (Said, 1971), and generally becomes thinner northwards. In north W. Qena area, the Naqus Formation is well exposed in the district between W. Um Arta and G. Somr El Qaa, but with variable thicknesses ranging between 30-50 m. Northwards of this district to W. El Dakhl and southwards to W. Qena, tbe Naqus Formation is markedly thinning until it is entirely missing. The maximum thickness (120 m) is preserved in the southern footslopes of G. Somr El Qaa. Such a section was probably a downthrown or low-lying faulted block relative to the contiguous blocks that were displaced and juxtaposed through post-Naqus -Pre-Malha tectonic movements. In the subsurface of the Gulf of Suez, the Naqus Formation is possibly equated to the informal "Nubia C" given by oil companies. Outside the Gulf area, the sandstones of the Naqus Formation have strong similarities with the facies No.3 of the Silurian Um Ras Formation which is exposed at the Egyptian-Sudanese border. This facies is made up of 80 m-thick, sheet-like, medium to coarse grained white sandstone, exhibiting frequently deformed cross-bedding (Klitzsch and Wycisk, 1987).

Abu Thora Formation

Synonymy: Ataqa Series, Kostandi (1959); Ataqa Group (Soliman and Abu El-Fetouh, 1969); Ataqa Formation (Weissbrod, 1969); Gilf Formation (Issawi and Jux, 1982); Abu Thora Member (Beleity *et al.*, 1986), and the described section of what is called Somr El Qaa Formation in W. El Dakhl area (Klitzsch *et al.*, 1990).

Author: Weissbrod (1981).

Type section: Um Bogma area, west-central Sinai (Lat 29° 00 N and Long. 33° 21 E).

Reference section: Upper reaches of W. El Dakhl, western side of the Gulf of Suez (Lat. 28° 41 N and Long. 32° 31 E).

Thickness: 90 m in Um Bugma area (Weissbrod, 1969 and 1981). At W. El Dakhl, it attains a thickness of about 70 m. Southwards, the thickness gradually decreases until the formation is entirely missing at the area between W. Um Tenassib and W. Ghazala (Figs. 1 and 3).

Boundaries: In the type area, the Abu Thora Formation overlies conformably the Lower Carboniferous Um Bogma Formation and underlies unconformably tbe Permo-Triassic sediments with occasional basaltic sills in-between (Weissbrod, 1969 and 1981). The Permo-Triassic rocks are called Budra Formation (Druckman *et al.* 1970) and Qiseib Formation (Abdallah *et al.*, 1963; and Barakat *et al.*, 1986). In local places in Um Bogma area, this formation rests unconformably on the Pre-Carboniferous Netafim Formation (Weissbrod, 1969). In the study area, the Abu Thora Formation is unconformably overlain by the Lower Cretaceous Malha Formation (Pl.4-c) and is separated by irregularly eroded layers of intensively rooted sandstone (0.5-2 m thick). On the other hand, it rests unconformably on different rock units including, from north to south, north to south, the Cambro-Ordovician Araba Formation (Pl.1-a) and the Pre-Carboniferous -Ordovician Naqus Formation respectively (Pl.1-f). The time gap of the unconformities between this formation and the encompassing rock units is relatively wider than that present in the type area.

Description: In the type area, the Abu Thora Formation consists mainly of white sandstone being quartzitic at the top with two shale horizons, containing in some localities, bituminous coal seams (Weissbrod, 1969 and 1981; Kora, 1984; and Beleity *et al.*, 1986). Bhattacharyya and Dunn (1986) subdivided this rock unit into a lower sandy unit and an upper shaly unit.

In the study area, the Abu Thora Formation is a white sandstone unit with grey to black shale at the top. It can be visually subdivided into two

members; a lower sandstone member and an upper shale-sandstone member (Fig. 2).

The lower member reaches an overall thickness of about 50 m. It is essentially made up of sandstone, whicb is geometrically organized into two types of lenticular bodies, intertonguing or truncating each other. The prominent type consists of very thick sandstone bodies. They are apparently massive but actually cross bedded with medium to thick tabular and trougb cross sets, indicating ENE to NE transporting direction. Generally they exhibit a fining upword regim, erosive soles and internal scouring. Internal scouring. These bodies show protruding knobs or knolls of smooth convex outlines (Pl.1-a). The other intertonguing bodies are internally thin, medium to thick horizontally bedded with rippled surfaces, graded lamination and occosionally contain root-like casts. They form inward recesses between the protruding cross-bedded bodies. Thin sandy conglomeratic lenses and gravelly layers of a single clast thick are encountered. They are common along the base of sandstone bodies or lie on the cross-bed foresets. The sandstone is strikingly white with surfacial pink and brown tarnish. It is very fine to medium grained, well sorted, rounded to subrounded and composed chiefly of clean quartz arenite. Tbis sandstone is economically exploited as glass sand along W. El Dakhl. In fact, this sandstone is mineralogically more mature than that of the underlying Naqus and Araba formations, which contain considerable quantities of altered feldspars and disintegrated granitic clasts. This noticeable difference was also noted by Bhattacharyya and Dunn (1986) in Sinai and along the Gulf of Suez.

The upper shale-sandstone member attains a thickness of about 20 m. It is readily recognized by its blackish sandy-shaly facies (Pl.4-c). This member consists of two sandstone units with shale beds in between (Fig. 2). The lower sandstone, up to 8 m thick, is characterized by large scale tangential and fish-bone cross-bedding as well as mega-ripples with internal small scale ripple cross-and flaser-lamination. The foresets are thin to thick bedded and indicate a N 50°-80° E transporting direction. The sandstone is white, weakly consolidated, fine to medium grained, and well sorted. The middle shale unit reaches a thickness up to 8 m and is made up of black laminated shale beds, intercalated with calcareous sandstone ledges. The shale unit contains frequent but delicate coalified plant remains. It forms either gentle slopes or inward recesses between the ledge-forming calcareous sandstone. The calcareous sandstone interbeds are hard, pinkish white, coarse but occasionally pebbly and thin to thick lenticularly bedded. Some layers yield badly preserved casts of marine fauna as *Productus* and *Spirifer* species as well as abundant trace fossils including *Nereis*, *Asterites*, *Scolicia*, *Planolites*, and *Chonderites* (Pl.4 d and e). The upper sandstone unit varies in thickness from place to place. It attains a maximum preserved thickness of up to 4 m, but laterally, even in the same locality, it is entirely eroded. This variation is probably due to the pre-Malha paleorelief and truncation history. The sandstone is greyish white, weakly consolidated, medium to coarse grained and well sorted. It is medium to thick massive bedded and is commonly dominated by disoriented fine and delicate kaolinitic rootlets.

Fossils and geologic age: In Um Bogma area, west-central Sinai, the sandstone and coal seams of this formation contain plant imprints, pollens, spores, and acritarcbs. Among the collected flora, prints of *Lepidodendron* and *Sigillaria* of Visean (Lower Carboniferous) affinity are the most common (Jongman and Heide, 1955; Kostandi, 1959; Said, 1962, and Weissbrod, 1969, 1981). Synelnikov (1959) and Omara and Schultz (1965) supported the Visean age on the basis of the palynological analysis of the coal seams from W. Abu Tbora, W. El Bedaa, and W. Abu Zarab, west-central Sinai. Recently, Kora (1984) identified 32 species of spores and acritarchs, which restrict or assign the Abu Thora Formation to the Upper Visean stage.

In the study area, especially at W. El Dakhl, Issawi and Jux (1982) equated stratigraphically this rock unit with the marine Permo-Carboniferous section exposed in W. Araba west

of the Gulf of Suez (refers to Rod El Hamal Formation of Abdallah and Adindani, 1963). They attested this correlation by their findings of *Equisetites* casts, *calamites* and Medullosa molds, which display advanced morphologic characters leading Issawi and Jux *(op. cit.)* to relate them to Permo-Carboniferous age. In the same locality (W. El Dakhl), however, Klitzsch *et al.* (1990) assigned this rock unit, which they called "Somr El Qaa Formation", an Early and Middle Carboniferous age. Their palenotological evidences include the following flora, fauna, and trace fossils: *Bothodendron aff depereti, Lepidodendron spetsbergense, L. veltheimii, Lepidophylloides sp., Leptophlocum rhombicum, Precyclostigma blakaense, Precyclostigma sp., Pseudolepidodendropsis scobiniformis, Nothorhacopteris argentinica,* as well as *Productus sp., Spirifer sp., Chonderites sp.* and tracks of sea urchins. Recently, the spores and acritarchs identified by A.N. El Barkooky (Personal communication) from the carbonaceous shale of W. El Dakhl, indicate also the Early Carboniferous age. Based on the present collection of the brachiopod casts and ichnogenera (previously mentioned) from this rock unit as well as the strong similarities with the well dated Abu Thora Formation of the Um Bogma area, Sinai, the Early Carboniferous age determined by Klitzsch *et al. (op. cit)* is recommended here. In the meantime, the present study does not confirm the application of the so called "Somr El Qaa" Formation of Klitzsch (1986) and Klitzsch *et al.* (1990) to represent this Carboniferous rock unit, because it never extend south of W. Hawashia and consequently does not occur at Somr El Qaa area, the type section of their proposed formtion. On the other hand, neither the lithologic aspects nor the faunal content and stratigraphic level of the Carboniferous rocks of W. El Dakhl support its correlation stratigraphically, with the Permo-Carboniferous section of W. Araba as done by Issawi and Jux (1982).

Geographic distribution and correlation: This rock unit occurs on both sides of the Gulf of Suez. It is recorded in the surface and subsurface. The surface outcrops are probably restricted to the central sector of the Gulf of Suez. Along the eastern (Sinai) side, the thickest exposure of this formation is measured at Um Bogma area. It attains a thickness of about 190 m, that gradually decreases to the east and south. This formation was previously called Upper Sandstone Series (Barron, 1907), Ataqa Series (Kostandi, 1969), Ataqa Formation (Said, 1962; and Weissbrod, 1969), and Ataqa Group, including: the Abu Zarab, Magharet El Maiah, and Hashash formations (Soliman and Abu El-Fetouh, 1969). Beleity *et al.* (1986) restricted the occurrence of the Abu Thora Formation (treated there as a member) to the Um Bogma area. They, and also all previous workers did not record any outcrop of this formation south of west-central Sinai. Recently, Klitzsch (1990) after field studies with Seilacher in 1983 and El Barkooky in 1988 proved that the sandstone strata (50-80 m thick) below the Carboniferous "Durba Shale" in SW Sinai are of Early Carboniferous age, and are not related to the underlying Lower Paleozoic Naqus Formation as considered by previous studies. They correlated these strata to the Lower Carboniferous Abu Thora Formation of Um Bogma area. The present study confirms this correlation.

In the western side of the Gulf, the Abu Thora Formation is exposed only at W. El Dakhl in the southeastern scarp of the South Galala High. It attains a thickness of about 70 m and wedges southward, until it disappears at the watershed area between W. Hawashia and W. Um Tenassib. Further to the north of W. El Dakhl and Um Bogma area, the Abu Thora Formation is not recorded on the surface. Its equivalent rocks in the subsurface as in Ataqa, Ayun Musa, and Abu Hamth wells attain greater thickness (277-355 m), and consist predominantly of shale with subordinate intercalations of sandstone and fossiliferous limestone. This shale-rich unit represents the Ataqa Formation as defined and described by Kostandi (1959) in its type locality (Ataqa well No.1). It probably forms the lateral facies change of the sand-rich unit of the Abu Thora Formation exposed in the south. The present work recommends the term Ataqa Formation

to represent the Lower Carboniferous shale-rich unit in the northern sector of the Gulf of Suez and the term Abu Thora Formation for the equivalent sandy unit exposed southward (i.e., Um Bogma -Durba - W. El Dakhl areas).

Outside the Gulf of Suez and Sinai, the Abu Thora Formation and its equivalent Ataqa Formation could be stratigraphically correlated with the Lower Carboniferous clastic sequence (50-100 m thick) described in Abu Ras Plateau, SW Egypt, by Menchikoff (1962) and Klitzsch (1979; 1983; and 1984). This sequence consists mainly of shallow marine to deltaic and fluviatile sandstone, siltstone and shale grading southward to purely fluvial sandstone (Klitzsch, 1984). Klitzsch and Lejal Nicol (1984) called these clastics "Wadi Malik Formation". They collected several Lycophytes, which as they stated, are closely similar to the flora identified by Jongman and Heide (1955) from the Lower Carboniferous sandstone of Um Bogma area, Sinai.

Malha Formation

Synonymy: Wadi Qena Formation (Kallenbach and Hendriks, 1986) and Dakhl Formation (Bandel *et al.*, 1987).

Author: Abdallah *et al.* (1963).

Type sections: W. Malha, western side of the Gulf of Suez (Lat. 29° ̀19 ̀23 N and Long. 32° 29̀ 22 È).

Refernce section: 1- water divide area between W. Abu Boaitheran and W. Rigla, north of Ras Gharib - El Sheikh Fadl asphaltic road, Eastern Desert. 2- southwestern upstreams of W. El Dakhl, western side of the Gulf of Suez.

Boundaries: Allover the Gulf of Suez and Sinai, the Malha Formation is invariably overlain by marine shales and marls of Cenomanian age (Raha or Galala formations). Along the study area, the Malha-Galala contact represents an erosional unconformity which is underlain by truncated paleosols containing intensive root- and bioturbated horizons (Pl.4-f and g). Above the contact, the base of the Galala Formation is marked by pebbly glauconitic sandstone layers rich in the trace fossil *Thallassinoides* and fragmented molluscan casts indicating proper shallow marine conditions. Southwards of the study area, this unconformable relationship and mottled paleosols were described by Bandel *et al.* (1987) and Hendriks *et al.* (1987) from W. Qena. Northwards, however, Bandel *et al.* (1987) stated that, the Malha Formation at El Galala El Bahariya, grades into the marine Cenomanian beds without unconformity. Conversely, Bhattacharyya and Dunn (1986) considered the Malha-Raha (Cenomanian) boundary, along the northeast Nubian Craton, an erosive contact with well developed zone of paleosols, signifying a period of prolonged subaerial weathering and non-deposition. The lower boundary of the Malha Formation represents also a regional unconformity allover the Gulf of Suez and Sinai. It overlies unconformably various rock units ranging in age from Carboniferous to Late Jurassic (Barakat *et al.*, 1986). Along the Tih scarp, west-central Sinai, it overlies unconformably either the Upper Jurassic Temmariya or the Jurassic Raqaba and/or the Permo-Triassic Qiseib formations (Barakat *et al.*, *op. cit.).* In southwest Sinai as well as in the type locality, it is underlain by the Qiseib Formation (Abdallah *et al.*, 1963; and Barakat *et al.*, 1986). South of the type locality, the time gap between this formation and the underlying rock units is rather wide and increases on going further south. At W. El Dahkl, the Malha Formation overlies the Lower Carboniferous Abu Thora Formation, while in Somr El Qaa - W. Hawashia area, it commonly truncates the Pre-Carboniferous -Lower Paleozoic Naqus Formation. However, in the last-mentioned area, but in a single local place, west of W. Abu Boaitheran, this formation is recorded for the first time, resting directly on the Precambrian Basement rocks (Pl.4-h). In Bir Timimit el Shifa area (40-50 km south of Somr El Qaa area), the direct contact between the Precambrian Basement and the Malha Formation (treated as W. Qena Formation) was also recorded by Hendriks *et al.* (1987) and Klitzsch *et al.* (1990).

PLATE 2

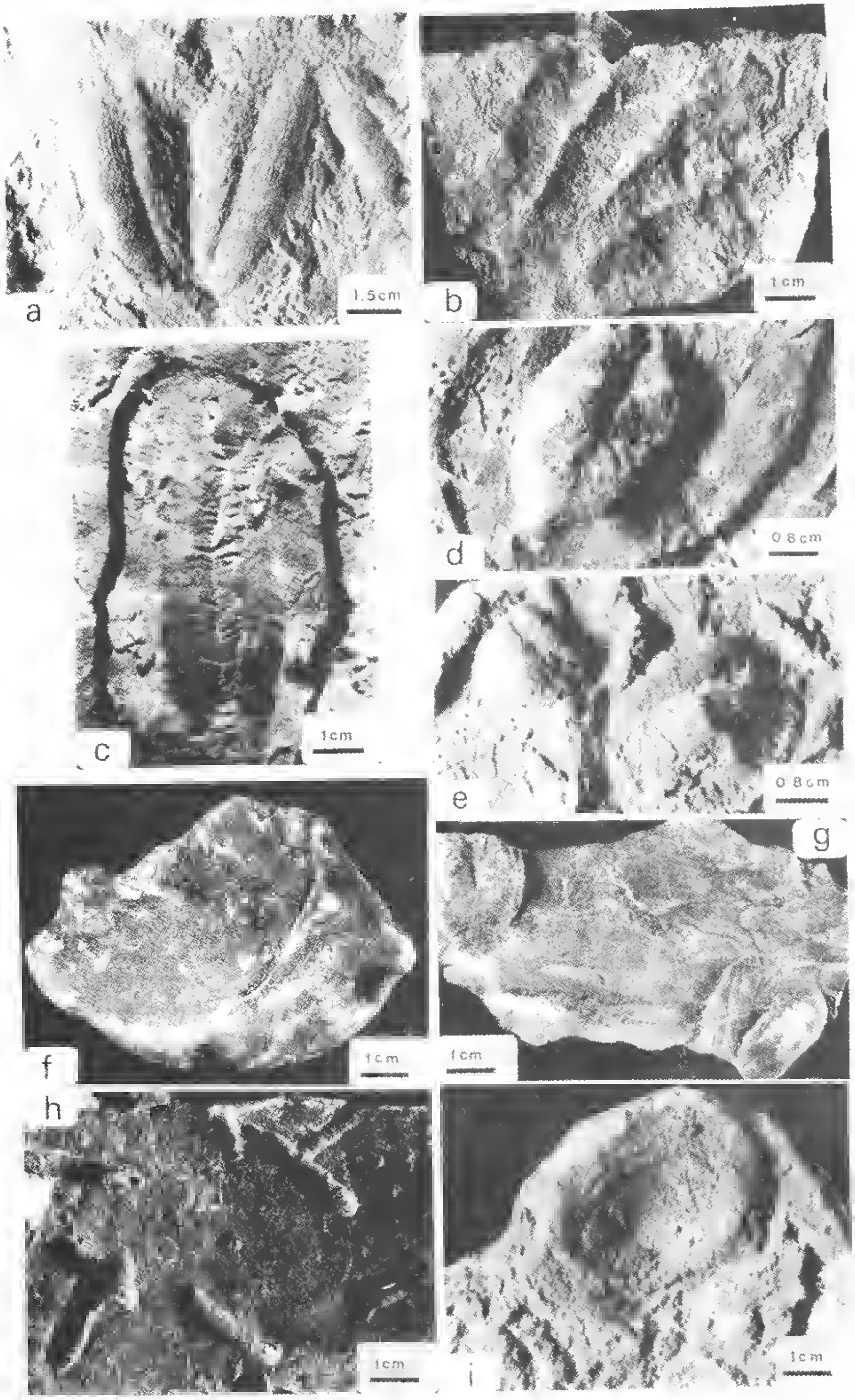

PLATE 2

a) ***Cruziana aegyptica***

Early Cambrian, Araba Formation (lower member), Somr El Qaa area, north W. Qena.

b) ***Cruziana sp.***

Early Paleozoic (Cambro-Ordovician), Araba Formation (Lower member), Somr El Qaa area, north W. Qena.

c and d) ***Cruziana arizonensis***

Early Paleozoic (Cambrian), Araba Formation (Lower member), W. Um Arta - El Dakhl area.

e and g) ***Rusophycus sp.***

Early Paleozoic (Cambro-Ordovician), Araba Formation (lower member), Somr El Qaa area, north W. Qena.

f) ***Arenicolites sp.***

Early Paleozoic (Cambro-Ordovician), Araba Formation (lower member), Somr El Qaa area, north W. Qena.

h) ***Bifungites***

Early Paleozoic (Ordovician ?), Araba Formation (lower and upper members), Somr El Qaa area -W. Um Arta.

i)***Bergauria sucta***

Early Cambrian, Araba Formation (lower member), W. Um Arta.

Outside the Gulf of Suez and Sinai, the Abu Thora Formation and its equivalent Ataqa Formation could be stratigraphically correlated with the Lower Carboniferous clastic sequence (50-100 m tbick) described in Abu Ras Plateau, SW Egypt, by Menchikoff (1962) and Klitzsch (1979; 1983; and 1984). This sequence consists mainly of shallow marine to deltaic and fluviatile sandstone, siltstone and shale grading southward to purely fluvial sandstone (Klitzsch, 1984). Klitzsch and Lejal Nicol (1984) called these clastics "Wadi Malik Formation". They collected several Lycophytes, which as they stated, are closely similar to the flora identified by Jongman and Heide (1955) from the Lower Carboniferous sandstone of Um Bogma area, Sinai.

Malha Formation

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Type sections: W. Malha, western side of the Gulf of Suez (Lat. 29° 19 23 N and Long. 32° 29 22 E).

Refernce section: 1- water divide area between W. Abu Boaitheran and W. Rigla, north of Ras Gharib - El Sheikh Fadl asphaltic road, Eastern Desert. 2- southwestern upstreams of W. El Dakhl, western side of the Gulf of Suez.

PLATE 3

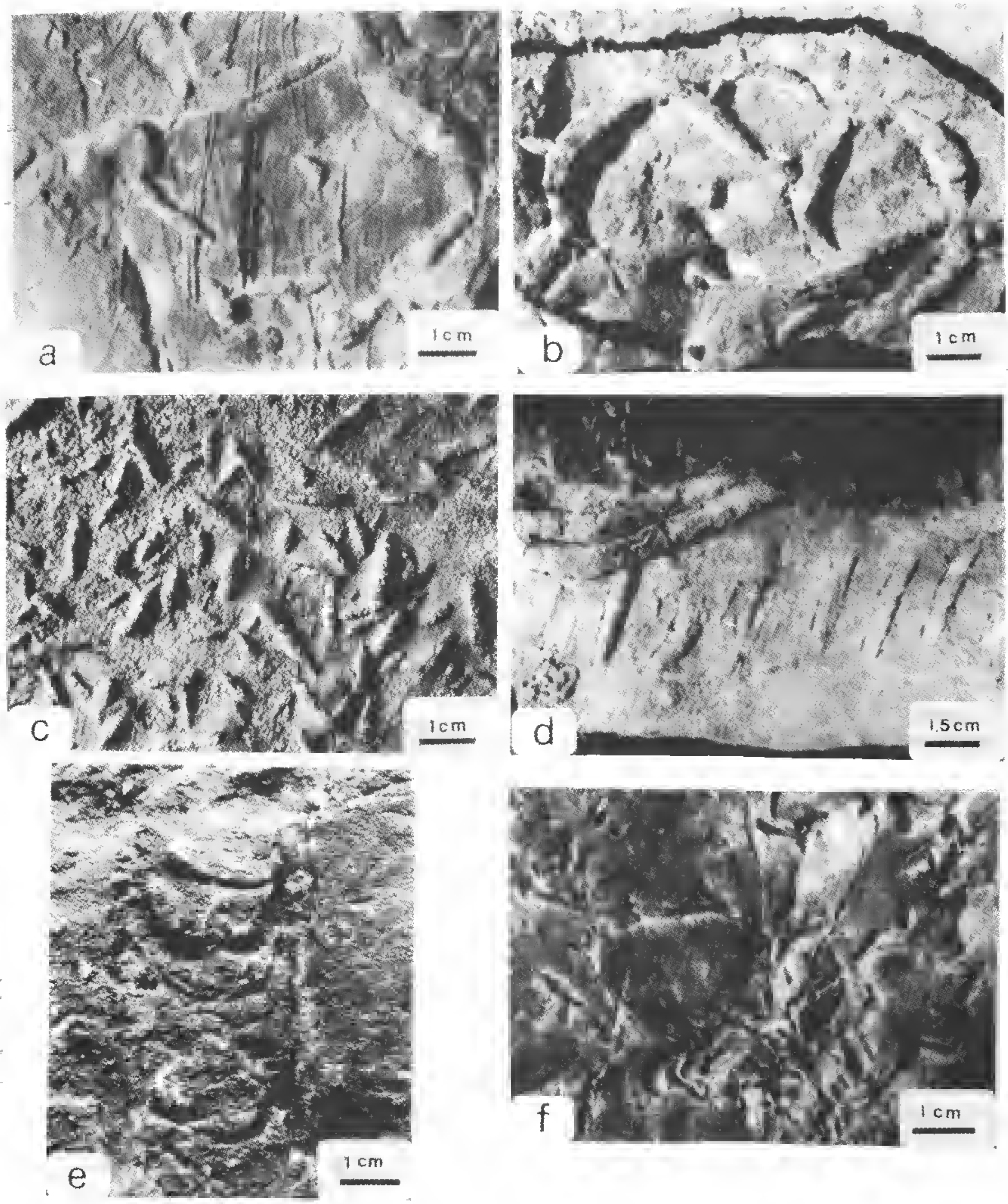

PLATE 3

a) *Dimorphichnus*

Early Paleozoic, Araba Formation, W. Um Arta - El Dakhl area.

b, c, and f) Problematic traces

Early Paleozoic, Araba Formation (lower member), Somr El Qaa and W. Um Arta.

d) *Cruziana sp.* and *Dimorphichnus*

Early Paleozoic, Araba Formation (lower member), W. Um Arta - El Dakhl area.

e) *Diplocraterion*

Early Paleozoic, Araba Formation (lower member), Somr El Qaa area, north W. Qena.

Boundaries: Allover the Gulf of Suez and Sinai, the Malha Formation is invariably overlain by marine shales and marls of Cenomanian age (Raha or Galala formations). Along the study area, the Malha-Galala contact represents an erosional unconformity which is underlain by truncated paleosols containing intensive root- and bioturbated horizons (Pl.4-f and g). Above the contact, the base of the Galala Formation is marked by pebbly glauconitic sandstone layers rich in the trace fossil *Thallassinoides* and fragmented molluscan casts indicating proper shallow marine conditions. Southwards of the study area, this unconformable relationship and mottled paleosols were described by Bandel *et* al. (1987) and Hendriks *et al.* (1987) from W. Qena. Northwards, however, Bandel *et* al. (1987) stated that, the Malha Formation at El Galala El Bahariya, grades into the marine Cenomanian beds without unconformity. Conversely, Bhattacharyya and Dunn (1986) considered the Malha-Raha (Cenomanian) boundary, along the northeast Nubian Craton, an erosive contact with well developed zone of paleosols, signifying a period of prolonged subaerial weathering and non-deposition. The lower boundary of the Malha Formation represents also a regional unconformity allover the Gulf of Suez and Sinai. It overlies unconformably various rock units ranging in age from Carboniferous to Late Jurassic (Barakat *et al.*, 1986). Along the Tih scarp, west-central Sinai, it overlies unconformably either the Upper Jurassic Temmariya or the Jurassic Raqaba and/or the Permo-Triassic Qiseib formations (Barakat *et al.*, *op. cit.)*. In southwest Sinai as well as in the type locality, it is underlain by the Qiseib Formation (Abdallah *et al.*, 1963; and Barakat *et al.*, 1986). South of the type locality, the time gap between this formation and the underlying rock units is rather wide and increases on going further south. At W. El Dahkl, the Malha Formation overlies the Lower Carboniferous Abu Thora Formation, while in Somr El Qaa - W. Hawashia area, it commonly truncates the Pre-Carboniferous - Lower Paleozoic Naqus Formation. However, in the last-mentioned area, but in a single local place, west of W. Abu Boaitheran, this formation is recorded for the first time, resting directly on the Precambrian Basement rocks (Pl.4-h). In Bir Timimit el Shifa area (40-50 km south of Somr El Qaa area), the direct contact between the Precambrian Basement and the Malha Formation (treated as W. Qena Formation) was also recorded by Hendriks *et al.* (1987) and Klitzsch *et al.* (1990).

Thickness: It is highly variable in both type locality and study area as well as in Sinai. It attains 50 m in the type area but ranging, in

PLATE 4

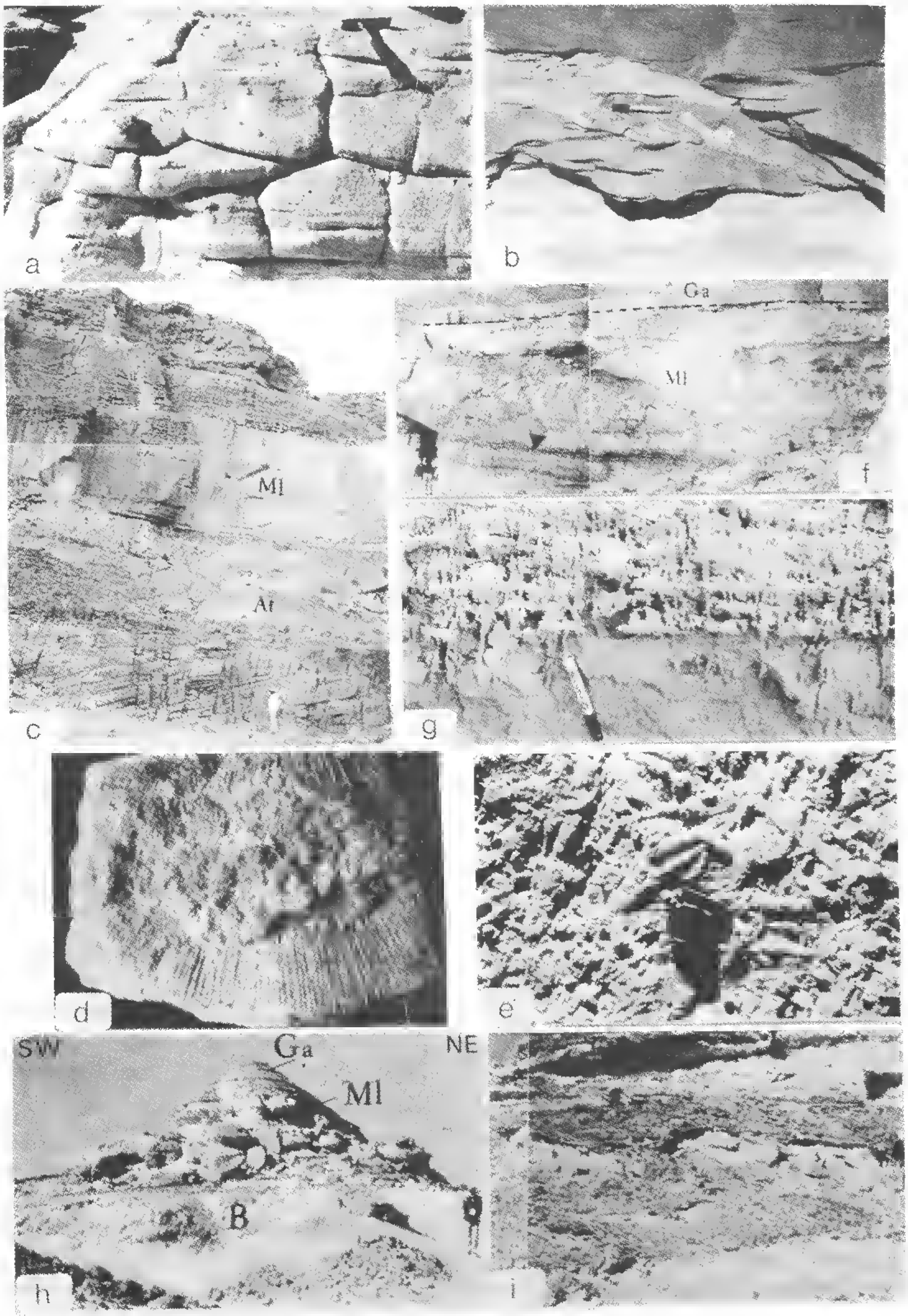

PLATE 4

a) Large discoidal quartz gravels form layers of single clast thick that armour the bases of internal erosion surfaces, upper part of the Naqus Formation, Somr El Qaa area.

b) Intraformational conglomerate lenses, consisting of locally reworked and imhricated sandstone rock fragments, upper part of the Naqus Formation, Somr El Qaa area.

c) The unconformahle contact between the Lower Carboniferous Abu Thora Formation and the Lower Cretaceous Malha Formation. Notice the Gilhert cross-bedded sandstone and the overlying slope-forming shale, forming the upper member of the Abu Thora Formation, W. El Dakhl.

d) Badly preserved *spirifer* cast collected from the upper member of the Abu Thora Formation, W. El Dakhl.

e) *Planolites* trace fossils collected from the upper member of the Abu Thora Formation, W. El Dakhl.

f) Contact hetween the Lower Cretaceous Malha Formation and the Cenomanian Galala Formation. The Malha Formation consists of fining upward subunits starting with ledge forming gravelly sandstone grading upwards to massive hedded and variegated clayey sandstone (paleosol), upstreams of W. Abu Boaitheran, north Somr El Qaa area.

g) Vertical and horizontal burrows of presumed root origin in the clayey sandstone intervals of the upper part of the Malha Formation, upstream of W. Abu Boaitheran.

h) Isolated conical hill of the Malha Formation resting nonconformahly on the Precambrian Basement rocks and underlying the Cenomanian Galala Formation, SW of W. Ahu Boaitheran.

i) Irregular hase of the Malha Formation displaying relief gradient, W. Ahu Boaitheran.

neighboring sections, between 40 and 135 m (Nakkady, 1958; and Ahdallah *et al.*, 1963). The thickest outcrop of this formation is measured in the section north of W. El Homur, in the southern cliffs of El Tih Plateau, Sinai, where it attains a thickness of about 330 m (Barakat *et al.*, 1986). Along the study area, the thickness is generally hetween 20 and 30m. It increases northward, where at W. El Dakhl, it reaches 40 m. A reduced thickness of less than 5 m was measured in the sections outcropping in the south of El Sheikh Fadl-Ras Gharih asphaltic road, and facing the southern cliff of G. Somr El Qaa. Further south, along W. Qena, Hendriks *et al.* (1987) mentioned that this formation attains a maximum thickness of 4 m in the south and of 50 m in the north. In the same area, however, Bandel *et al.* (1987) and Klitzsch *et al.* (1990) measured about 100 m of this rock unit, hut from their description, it seems that they lumped or included parts of the underlying Paleozoic sandstones of the Naqus Formation with that of the Malha Formation.

Description: In the type area, the Malha Formation is made up of white, pink and violet sandstone with some kaolinitic clay lenses (Abdallah *et al.*, 1963). Some of these lenses are economically quarried hoth in the Gulf of Suez and west-central Sinai.

In Somr El Qaa area, the Malha Formation is composed mainly of cross-stratified and massive sandstones with few conglomeratic lenses and mudstone intercalations (Fig. 2.). Northwards, at W. El-Dakhl, the mudstone fraction gradually increases. These clastics are organized into thin.

fining-upward subunits (1-5 m thick) (Pl.4-f). Each one has a basal erosion surface that is almost flat to gently dipping, except the sole of the lowermost unit which displays an observable relief gradient up to 2 m (Pl.4-i). Most of the subunits start with lenticular bodies of gravelly sandstone and grade upwards to irregular intervals of massive bedded clayey sandstone, which is cut by the erosion surface of the succeeding subunit. On these erosional surfaces, scattered quartz pebbles ferruginous and silicified wood fragments as well as reworked debris of the underlying clayey sandstone are commonly recorded. The gravelly sandstone bodies (0.5 - 2 m thick) are composed of greyish to reddish white sandstones of very coarse to medium grain size. They are weakly consolidated and partially cemented by barite. These bodies exhibit, internally, cosets of tabular and trough cross lamination of northward transporting direction. The massive, bedded intervals are made up of very fine to coarse-graind and poorly sorted sandstone with clayey (mostly kaolinitic) matrix. They are poorly bedded, but, in some horizons, badly preserved traces of horizontal and cross-lamination are observed. Vague vertical burrows of presumed root origin are occasionally recognized. The massive intervals exhibit characteristic weathering features, which vary in intensity from place to place even in the same locality. These features include mottling, diffusion and irregular lamination of various colours, desiccation of the still preserved parent sandstone into irregular fragments of variable sizes that are coated by films of iron oxides and clayey materials. In deeply weathered horizons, the original sandstone is intensively obliterated to cohesive sandy, ferruginous and kaolinitic mudstone, forming hard, desiccated pseudo-layers or bands of different colours.

Fossils and geologic age: Except for the above mentioned badly preserved ferruginous fossil woods, as well as the vague vertical and horizontal burrows, the Malha Formation in the study area has provided no index body fossils. In the type area and nearby sections, Abdallah *et al.* (1963) described fossiliferous marine interbeds in the upper part of the Malha Formation. These beds yield *Ostrea falco*, *O. baussignaulti*, *O. palaeomon*, *O. renevierieos*, and *Aspidiscus sp.* which indicate an Early Cretaceous age. In the Gulf of Suez region, Hassanein (1970) and Abdel Shafi (1980) identified the following foraminiferal assemblages from the lower part of the Malha Formation; *Globigerina infracretacea*, *G. quadrata*, *Bolivina sinaica*, *Cribrostomaides sinaica*, *Discorbis beadnelli*, *D. Minutus*, *Flabellamina aegyptiaca*, *F. magna*, *F. seratagensis*, *Spiroplectammina arabicus*, *S. obsura*, *Rectoglanduling multabilis*, *Lagena globosa*, and *Guadryina rugosa*. In west-central Sinai, Barakat *et al.* (1986) recorded leaves of genera *Phlebopteris* and *Otozamites* which assigned the Malha Formation a Late Jurassic-Early Cretaceous age. Along W. Qena, Bandel *et al.* (1987) called this rock unit "El Dakhl Formation" and dated it Early Cretaceous. Hendriks *et al.* (1987) and Klitzsch *et al.* (1990) recognized silicified wood, bone fragments, and several burrow horizons in this rock unit at W. Qena and dated it Albian-Cenomanian. On the ground of palynological content which includes forty-three species of gymnosperms (53.5%) and pteridophytes (45.5%), Aboul Ela (1990) determined a Middle Jurassic age for some kaolinitic lenses from the lower part of the Malha Formation in west-central Sinai (G. Musabaa Salama). According to the above age determinations and the stratigraphic position of this rock unit, it is dated in the study area to the Early Cretaceous age.

SEDIMENTARY FACIES AND DEPOSITIONAL ENVIRONMENT

The Pre-Cenomanian clastics of north W. Qena area assume various sedimentary facies which reflect accumulation on a tectonically unstable alluvial plain that was temporarily encroached from the north by shallow seas. The lithologic aspect, biogenic and physical sedimentary structures reveal the classification of these clastics into ten continental and marine facies; their characters and environmental conditions are briefly summarized and interpreted in Table 2. The occurrence of several sedimentary facies of different

environmental regimes throughout the Cambrian-Albian time suggests changes in the paleotopographic setting of the area in relation to the adjacent seas with changes in the sediment supply. These in turn are related to an instability in the tectonic and paleoclimatic parameters that prevailed during or after the accumulation of each lithounit.

CONCLUSIONS

The exposed Pre-Cenomanian sequence of north W. Qena - W. El Dakhl landstretch reaches an overall thickness of about 200 m. It consists mainly of poorly fossiliferous sandstones with subordinate mudstone and conglomerate lenses, and ranges in age from E. Cambrian to E. Cretaceous. Although this sequence has been investigated by many workers during the last decade, the present study, however, reveals much controversy and misinterpretation concerning the proposed rock unit nomenclatures, formational boundaries, thicknesses, and age determinations. This investigation permits, to a certain extent, a better understanding of the lithostratigraphy, distribution, and paleo-environments of these clastics. The following main items could be summarized.

1- Along the southern sector of the study area, from G. Somr El Qaa to W. Ghazala, the worked out sequence is identified and classified into three formal rock units; the Araba Formation Cambro-Ordovician); the Naqus Formation (Ordovician - Pre-Carboniferous ?); and the Mallha Formation (E. Cretaceous). Northwards to W. Um Arta, the Lower Carboniferous Abu Thora Formation is unconformably incorporated between the Naqus and Malha formations.

2- No Carboniferous rocks are recorded in the southern part of the area (G. Somr El Qaa). The previous assignment of the Carboniferous age to the rocks of this area lack any concrete paleontologic or stratigraphic evidence, and was based solely on the hasty correlation with the definite Carboniferous rocks of Sinai, W. El Dakhl, and El Gilf El Kebir plateau (SW Egypt). Accordingly, the previously proposed Carboniferous rock units, e.g. Gilf Formation of Issawi and Jux (1982), Somr El Qaa Formation of Klitzsch (1986), and the Um Bogma Formation (used by Bandel *et al.*, 1987), should be Omitted from the Paleozoic stratigraphy of Somr El Qaa -W. Hawashia area.

3- Throughout the study area, the Araba Formation is easily divided into two members; the lower mudstone - sandstone *(Cruziana-rich)* member and the upper sandstone *(Scolithos-rich)* member. The contact between them, in Somr El Qaa area, is sharp and marked by a thin paleosol horizon with local accumulation of angular Basement rock fragments. Such a contact may refer to a period of subaerial exposure and soil formation, as well as to the existence of an adjacent exposed Basement rocks, from which the rock debris were locally reworked. However, in the north, at W. El Dakhl-W. Um Arta stretch, this boundary seems to be gradational, without visible erosional features. The local uplifting and shallowing conditions that prevailed in the southern portion, prior to and during the accumulation of the upper member, could also be evidenced by the frequent occurrence of the long *Scolithos* burrows penetrating the very coarse and gravelly sandstones of the upper member. These bores, which occur densely in the agitated intertidal zone (Collinson and Thompson, 1982) are less distinct in the northern part of the area.

4- Allover the investigated area, the Naqus Formation is distinguished by its clear white colour, abundance of quartz gravels, as well as the frequent deformation of its cross-sets into recumbent and convolute beds. These penicontemporaneous deformational structures indicate a plastic deformation of partially liquified and rapidly deposited sands. Such deformation was probably due to an external force, *e.g.* earthquake shocks. Should such interpretation be correct, it may support the tectonic instability and gradual uplifting that affected the area (and the source area) since the accumulation of the upper member of the Araba Formation.

5- The white sandstones of the Carboniferous Abu Thora Formation are differentiated from those of the Naqus Formation by their high textural and mineralogical maturity and the absence of the above deformational structures.

ROCK UNIT	FACIES NO.	FACIES CHARACTERISTICS			Depositional Environments
		Lithology	Sedimentary Structures	Faunal Content	
Malha Fm.	10	Clayey sandstone and sandy mudstone with scattered gravels.	Poorly bedding, mottling, diffusion coloures, desication, badly preserved cross - and horizonal lamination, coloured pseudolayers and internal erosion surfaces.	Reworked fossil woods and burrows of presumed root origin.	Paleosols
	9	Sandy conglomerate and gravely medium to coarse - grained sandstone.	Erosively based lenticular bodies with internal tabular and trough cross lamination	Reworked fossil woods.	Shallow braided alluvium
Abu Thora Fm.	8	Grey to black shale interbedded with sandstone.	Very large scale (Gelbert) tangential and fishbone cross-bedding ; megaripple, small ripple cross- and flaser lamination and lenticular bedding in sandstone fraction. Horizontal lamination in mudstone interbeds.	Coalified plants, root-lets, brachiopod casts and abundant marine trace fossils.	Marine shoreline (Swamp)
	6,7	Facies 6 & 7 are composed of fine to medium grained well sorted sandstone with few gravel lenses	6 : very thick bodies of tabular and trough cross-bedding, channeling and scour and fill. 7: Medium to thick horizontally bedded with wavy and rippled surface and graded lamination.	Few casts of roots and rootlets.	Fluviatile meandering and abandoned channels.
Naqus Fm.	5	Gravely medium to coarse grained sandstone with few conglomerate and mudstone lenses.	Facies 4 & 5 are made up of non-cyclic to fining upward lenticualr bodies consisting internally of long (up to 10 m length) tabular and trough cross-bedding with several reactivation surfaces, scour and fill, parallel lamination and frequent synsedimentary deformation structures (overturned, recumbent cross sets and convolute lam-ination).	Barren	Sandy to gravely shallow fluviatile braided channels.
	4	Medium to coarse grained sandstone with scattered granules.			
Araba Fm.	3	Coarse to very coarse grained sandstone with few gravel lenses.	Low angle trought-, tabular- and herringbone cross-bedding forming fining - upward lenticular bodies.	Abundant <u>Scolithos</u> burrows with <u>Bifungites</u>	Tidal channels
	2	Interbedded sandy mudstone and micaceous sandstone with few conglomerate.	Coarsening upward subunits with internal lenticular and wavy bedding, flaser, parallel and cross-lamination. Ripple marks desiccation cracks, and gradded bedding. Poorly bedding, desiccation, mottling, diffusion coloures and weathering in the top.	Abundant <u>Cruziana</u> assemblages. Vertical burrows and iron coneretion in the top.	Off-shore or Estuaries.
	1	Coarse grained sandstone and conglomerate	Flat, undulated and low-angle bedding, with megaripples and antidunes.	barren	Fore-shore

Table (2) : Facies and paleo-environments of the sutdied Pre-Cenomanian Clastics.

6- In few isolated hills, at the upstreams of W. Abu Boaitheran, the Naqus Formation overlaps nonconformably the Precambrian Basement rocks. Sucb relationship may indicate that the Basement rocks of this sector were topographically high (due to Precambrian faulting) and stood above the surrounding depositional level during the accumulation of the Araba Formation, where the upper member partially covered the downslopes of tbe Basement rocks.

7- Three regional unconformities coinciding with the bases of tbe Abu Tbora, Malha, and Galala formtions are recognized. They are well traced at W. El Dakhl, while at Somr El Qaa area, tbe lower two surfaces concourse together, giving an unconformity with a long time gap between the Malha and Naqus formations. From N to S, the Abu Thora and Malha formations are unconformably underlain by different rock units. Several tectonic movements, accompanied by block faulting and erosion of contiguous heterochronous blocks of different elevations, are the main element responsible for these unconformities, as well as for the distribution and the thickness change of the recorded rock units. The thinning and missing of tbe Naqus Formation in the norhtern part of the area may reflect that the pre-Abu Thora uplifting and erosion were more intense in such sector relative to the southern part. The confined occurrence of the Carboniferous deposits to the nortbern sector could be explained by two ways; firstly, with tbe beginning of the Carboniferous time, the southern sector was elevated as a positive area, relative to the northern part which received generally ENE trending paleostreams, depositing the sandstone of the Abu Thora Formation. The second assumption is that the Carboniferous deposits were covering the entire area and the present distribution was attributed to the post-Abu Thora-pre-Malha tectonic movements and subsequent erosion which, in turn, were intense in the southern blocks.

8- The various sedimentary facies of the Pre-Cenomanian clastics reflect a fluviatile sedimentation on an alluvial plain through a series of braided and meander channels interrupted by periods of flood plain and soil formation. Such an alluvial plain was temporarily encroached from the north by shallow seas. Shallow marine deposits representing, at least, two episodes of sea invasion (Cambro-Ordovician and Lower Carboniferous seas) are well preserved through out the recorded succession. On the other hand, no sedimentary facies or diagnostic criteria reflect a glacial or fluvioglacial deposition as assumed by some previous workers for tbe Naqus Formation.

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